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United States Patent and Trademark Office

July 12, 2000

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE UNDER 35 USC 111.

APPLICATION NUMBER: ***09/337,895***
FILING DATE: ***June 21, 1999***

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

By Authority of the
COMMISSIONER OF PATENTS AND TRADEMARKS

H. L. Jackson

H. L. JACKSON
Certifying Officer

Attorney's Docket No. 9537.2035

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Box Patent Application
Assistant Commissioner for Patents
Washington, D.C. 20231

NEW APPLICATION TRANSMITTAL

Transmitted herewith for filing is the patent application of

Inventor(s): Ricky BENNETT and Charles MONCAVAGE

For (title): HYDRAULIC TOOLING FIXTURE

1. Type of Application

This new application is for a(n)

- ☒ Original (nonprovisional)
- ☐ Design
  - ☐ Plant
- ☐ Divisional.
- ☐ Continuation.
- ☐ Continuation-in-part (C-I-P).

CERTIFICATION UNDER 37 CFR 1.10
I hereby certify that this New Application Transmittal and the documents referred to as enclosed therein are being deposited with the United States Postal Service on this date June 21 , 1999, in an envelope as "Express Mail Post Office to Addressee" Mailing Label Number EL 228 701 573 US, addressed to the. Assistant Commissioner for Patents, Washington, D.C. 20231.

Sharon Meyer
(type or print name of person mailing paper)

Sharon Meyer
(signature of person mailing paper)

2. **Benefit of Prior U.S. Application(s) (35 U.S.C. 119(e), 120, or 121)**

☐ This new application being transmitted claims the benefit of prior U.S. application(s). Enclosed are ADDED PAGES FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF PRIOR U.S. APPLICATION(S) CLAIMED.

3. **Papers Enclosed That Are Required for Filing Date under 37 C.F.R. 1.53(b) (Regular) or 37 C.F.R. 1.153 (Design) Application**

15 Pages of specification

8 Pages of claims

1 Pages of Abstract

8 Sheets of drawing

☒ formal

☐ informal

☐ The enclosed drawing(s) are photograph(s), and there is also attached a "PETITION TO ACCEPT PHOTOGRAPH(S) AS DRAWINGS." 37 C.F.R. 1.84(b).

4. **Additional papers enclosed**

☐ Preliminary Amendment

☐ Information Disclosure Statement (37 C.F.R. 1.98)

☐ Form PTO-1449 (PTO/SB/08A and 08B)

☐ Citations

☐ Declaration of Biological Deposit

☐ Submission of "Sequence Listing," computer readable copy and/or amendment pertaining thereto for biotechnology invention containing nucleotide and/or amino acid sequence.

☐ Authorization of Attorney(s) to Accept and Follow Instructions from Representative

☐ Special Comments

☐ Other-

5. **Declaration or oath**

☐ Enclosed is an executed original declaration/power of attorney

Executed by

☐ inventor(s).

☐ legal representative of inventor(s).
37 C.F.R. 1.42 or 1.43.

☐ joint inventor or person showing a proprietary interest on behalf of inventor who refused to sing or cannot be reached.

☐ This is the petition required by 37 CFR 1.47 and the statement required by 37 CFR 1.47 is also attached. *See* item 13 below for fee.

☒ Not Enclosed.

☐ Application is made by a person authorized under 37 CFR 1.41(c) on behalf of *all* the above named inventor(s).

(*The declaration or oath, along with the surcharge required by 37 CFR 1.16(e) can be filed subsequently*).

☐ Showing that the filing is authorized.
(*not required unless called into question. 37 CFR 1.41(d)*)

6. **Inventorship Statement**

The inventorship for all the claims in this application are:

☒ The same.

or

☐ Not the same. An explanation, including the ownership of the various claims at the time the last claimed invention was made.

☐ is submitted.

☐ will be submitted.

7. **Language**

☒ English

☐ Non-English

☐ The attached translation is a verified translation. 37 C.F.R. 1.52(d).

8. **Assignment**

☒ An assignment of the invention

☐ is attached. A separate ☐ "COVER SHEET FOR ASSIGNMENT (DOCUMENT) ACCOMPANYING NEW PATENT APPLICATION" or ☐ FORM PTO 1595 is also attached.

☒ will follow.

☐ The prior application is assigned to , recorded at reel/frame numbers .

9. **Certified Copy**

Certified copy(ies) of application(s)

Country	Appln. no.	Filed
Country	Appln. no.	Filed
Country	Appln. no.	Filed

from which priority is claimed

☐ is (are) attached.

☒ will follow.

10. Fee Calculation (37 C.F.R. 1.16)

A. ☒ Regular application

CLAIMS AS FILED					
Number filed			Number Extra	Rate	Basic Fee 37 C.F.R. 1.16(a) $760.00
Total Claims (37 CFR 1.16(c))	29	- 20 =	9	x $ 18.00 =	162
Independent Claims (37 CFR 1.16(b))	6	- 3 =	3	x $ 78.00 =	234
Multiple dependent claim(s), if any (37 CFR 1.16(d))				+ $ 260.00 =	$

☐ Amendment cancelling extra claims is enclosed.

☐ Amendment deleting multiple-dependencies is enclosed.

☐ Fee for extra claims is not being paid at this time.

Filing Fee Calculation $1156

B. ☐ Design application
($330.00 - 37 CFR 1.16(f))

Filing Fee Calculation $

C. ☐ Plant application
($530.00 - 37 CFR 1.16(g))

Filing Fee Calculation $

DOCSNY1 585875.1

11. Small Entity Statement(s)

☐ Verified Statement(s) that this is a filing by a small entity under 37 CFR 1.9 and 1.27 ☐ is (are) attached . ☐ will follow.

☐ Status as a small entity was claimed in prior application

/ , filed on , from which benefit is being claimed for this application under:

35 U.S.C. ☐ 119(e),
☐ 120,
☐ 121,
☐ 365(c),

and which status as a small entity is still proper and desired.

☐ A copy of the verified statement in the prior application is included.

Filing Fee Calculation (50% if **A, B** or **C** above) $ _____

12. Request for International -- Type Search (37 C.F.R. 1.104(d))

(complete, if applicable)

☐ Please prepare an international-type search report for this application at the time when national examination on the merits takes place.

13. **Fee Payment Being Made at This Time**

☒ Not Enclosed

☒ No filing fee is to be paid at this time.
(This and the surcharge required by 37 C.F.R. 1.16(e) can be paid subsequently.)

☐ Enclosed

☐	Basic filing fee	$ _____
☐	Recording assignment ($40.00; 37 C.F.R. 1.21(h)) (See attached "COVER SHEET FOR ASSIGNMENT ACCOMPANYING NEW APPLICATION".)	$ _____
☐	Petition fee for filing by other than all the inventors or person on behalf of the inventor where inventor refused to sign or cannot be reached ($130.00; 37 C.F.R. 1.52(d) and 1.17(k))	$ _____
☐	For processing an application with a specification in a non-English language ($130.00; 37 C.F.R. 1.52(d) and 1.17(k))	$ _____
☐	Processing an retention fee ($130.00; 37 C.F.R. 1.53(d) and 1.21(l))	$ _____
☐	Fee for international-type search report ($40.00; 37 C.F.R. 1.21(e))	$ _____
	Total fees enclosed	$ _____

14. **Method of Payment of Fees**

☐ Check in the amount of $ .00.

☐ Charge Account No. _____ in the amount of $.

A duplicate of this transmittal is attached.

15. Authorization to Charge Additional Fees

☐ The Commissioner is hereby authorized to charge the following additional fees required by this paper and during the entire pendency of this application to Account No. 15-0665.

- ☐ 37 C.F.R. 1.16(a), (f) or (g) (filing fees)
- ☐ 37 C.F.R. 1.16(b), (c) and (d) (presentation of extra claims)
- ☐ 37 C.F.R. 1.16(e) (surcharge for filing the basic filing fee and/or declaration on a date later than the filing date of the application)
- ☐ 37 C.F.R. 1.17 (application processing fees)
- ☐ 37 C.F.R. 1.18 (issue fee at or before mailing of Notice of Allowance, pursuant to 37 C.F.R. 1.311(b))

16. Instructions as to Overpayment

☐ Credit Account No. 15-0665

☐ Refund

SIGNATURE OF ATTORNEY

Reg. No. 41,943

Stephen J. Lieb
(type or print name of attorney)

Tel. No. (212) 506-5000

ORRICK, HERRINGTON & SUTCLIFFE LLP
666 Fifth Avenue
New York, New York 10103-0001

DOCSNY1:585875.1

☐ **Incorporation by reference of added pages**

☐ Plus Added Pages for New Application Transmittal Where Benefit of Prior U.S. Application(s) Claimed

Number of pages added _____

☐ Plus Added Pages for Papers Referred to in Item 4 Above

Number of pages added _____

☐ Plus "Assignment Cover Letter Accompanying New Application"

Number of pages added _____

☒ **Statement Where No Further Pages Added**

☒ This transmittal ends with this page.

HYDRAULIC TOOLING FIXTURE

Field of the Invention

This invention relates to a tooling fixture to support or clamp a workpiece. In particular, this invention relates to a hydraulic fixture for supporting a flexible substrate such as a printed circuit board in a screen printing machine or placement machine.

Background of the Invention

Fabrication of large volumes of electronic circuitry is economically accomplished using automated equipment. According to one known process a viscous solder paste is applied to selected areas of a printed circuit board through a stencil in a screen printing machine. Electronic components are then placed on the applied solder paste using a placement machine (also known as a pick-and-place machine). The printed circuit board and components are then heated in a reflow oven to a temperature sufficient to melt the paste, causing it to flow over the leads of the components and adjacent areas of the printed circuit board, thereby forming solder joints and completing the electronic circuit.

Within the screen printing machine a pair of conveyor belts support the printed circuit board by its edges. The conveyor belts move the board into the machine and position it relative to the stencil. A tooling fixture below the underside of the board is raised so that it presses upward on the lower surface of the board to provide support for the board during the printing process. The board and tooling are then raised until the top surface of the board contacts the stencil. A printhead applies the solder paste to the top surface of the stencil and presses the paste against the stencil. Pressure

applied by the printhead forces solder through holes in the stencil and onto the top surface of the board. The tooling fixture prevents the board from flexing away from the stencil as pressure is applied by the printhead.

Conveyor belts also move the circuit board through the placement machine. After solder is applied to the board by the screen printing machine, the board is moved into the placement machine and positioned relative to a robotic pick-and-place head. A tooling fixture located below the board is raised to support the underside of the board. Under the control of a program that defines the proper location of each of the components of the circuit, the pick-and-place head sequentially presses each component onto its proper location on the printed circuit board. The tooling fixture prevents the board from flexing as pressure is applied by the pick-and-place head.

Where components are placed on only one surface of the board, the tooling fixtures merely have to support a flat surface and only slight modifications to the fixtures need to be made to accommodate boards with different linear dimensions. However, in order to better utilise the surface area of printed circuit boards and produce more compact circuitry, components are often placed on both surfaces of the board. Such a board is processed first using tooling fixtures designed to support the flat, unpopulated lower surface of the board while solder paste and components are applied to the top of the board. The board is then turned over and components are placed on the other side of the board. A second tooling fixture is required to support the surface of the board now populated by components. This second tooling fixture must conform to the three-dimensional surface created by the components. Since each different circuit layout has a different three-dimensional shape, this second tooling fixture must be customised for each layout.

One way to provide a customised, three-dimensional tooling fixture is to manually assemble blocks on the top surface of the tooling fixture that are shaped to contact the portions of the board not populated by components. This method is time consuming because an operator must reposition the blocks each time a different board is processed. This method is particularly cumbersome when a large number of different types of circuit boards are fabricated on the same assembly line.

Another method is to provide an array of electronically addressable posts that are either retracted in positions where a component is attached or extended where they can contact the board surface to provide support. A computer program directs the tooling fixture to configure the posts to conform to each printed circuit board that is fabricated. This method provides a faster means to change from one tooling configuration to another than the manual assembly of blocks. However, a separate computer database must be created for the layout of each board. Further, since no support is provided to the board in areas covered by components, certain portions of the board may be inadequately supported. Unsupported portions of the board may flex during processing resulting in misalignment between the stencil or the pick-and-place head and the board.

Yet another method is to provide a robot mechanism to automatically take support pillars from a reservoir and place them in the required positions to support the board. This method is faster and more consistent than manually placing support blocks, but needs a separate computer database for each board type to define where pillars should be placed and can only provide support where there is clear space on the board for the pillar.

Prior to using a customised fixture with a new board layout, an operator must carefully inspect the fit between the tooling fixture and the board to make certain that misalignment and

dimensional tolerances do not cause an extended post, positioned pillar, or a manually positioned block to contact a component. Such contact will cause the tooling fixture to flex the board upward resulting in misplacement of the solder paste or components. More importantly, flexure of the board upward against the stencil can cause damage to the stencil or printhead of the screen printing machine.

Inspection of the tooling fixture each time a new type of board is fabricated complicates the manufacturing process and lowers throughput. Further, if the operator fails to properly inspect the fit between the board and the fixture large numbers of misaligned boards may be produced or costly damage to the equipment may result.

Furthermore, even when a fabrication line produces only a single type of printed circuit board, each side of the board requires a different tooling fixture surface. A "flat" tooling fixture supports the unpopulated side of the board while the first side is screen printed and populated with components, and then a customised fixture supports the now populated side while the second side of the board is screen printed and populated. This tooling change reduces the throughput of the fabrication line.

Summary of the Invention

In view of the above-identified problems with known methods for forming tooling fixtures it is an object of the present invention to provide a tooling fixture that conforms to an uneven surface without having been configured beforehand.

It is another object of the invention to provide a tooling fixture that supports an uneven surface formed by a printed circuit board with components fixed thereon within a screen printing machine.

It is yet another object of the invention to provide a tooling fixture that supports an uneven surface formed by a printed circuit board with components fixed thereon within a placement machine.

It is a still further object of the invention to provide a tooling fixture that adapts to the surface of populated and unpopulated printed circuit boards.

It is a still further object of the invention to provide a tooling fixture that supports a workpiece using an array of hydraulic cylinders driving a respective array of pistons.

According to one aspect of the present invention a block is provided with a plurality of cylinders. Each cylinder surrounds a piston that drives a rod extending out of the top surface of the block. The cylinders are connected with a pressure sensor and an accumulator. A controllable valve is connected between the accumulator and the cylinders. Opening the valve allows hydraulic fluid to flow between the cylinders and the accumulator. The pressure sensor monitors the hydrostatic pressure of the hydraulic fluid in the cylinders. A compressed air source is connected to the accumulator through a further valve, such that when this valve is opened a force is generated to drive fluid into the cylinders, thereby causing the pistons to extend from the block. Similarly a vacuum source is also connected to the accumulator through a third valve, such that with this valve open and the compressed air valve closed, a vacuum is applied to the accumulator to draw fluid from the cylinders, thereby causing the pistons to retract into the block. The pressure sensor and the

valve are connected with a controller that opens and closes the valve in response to a control sequence and the hydrostatic pressure in the cylinders.

The tooling fixture according to this aspect conforms to an uneven surface as follows. The controller opens the fluid valve and the vacuum valve to draw fluid from the cylinders causing the pistons to retract the rods into the block. A workpiece is positioned above the fixture. The workpiece can be substantially flat or can have three-dimensional structures fixed thereon. According to one embodiment, the workpiece is a printed circuit that is either populated with components or else unpopulated. The controller closes the vacuum valve and opens the compressed air valve, forcing fluid into the cylinders and raising the rods. When all of the rods have contacted the surface of the workpiece, the pressure of the fluid sensed by the pressure sensor rises. When this pressure reaches a predetermined threshold, the controller closes the fluid valve and the compressed air valve, and the positions of the rods are fixed. Force applied to the top surface of the workpiece, for example by the printhead of a screen printing machine, is opposed by the rods and deflection of the workpiece is prevented.

Brief Description of the Drawings

Fig. 1 is a cross-sectional view of a tooling fixture according to an embodiment of the invention;

Fig. 2 is a cross-sectional view of a piston used in conjunction with the embodiment of Fig. 1;

Figs. 3-5 are cross-sectional views of the embodiment of Fig. 1 illustrating a method of operation according to the invention;

Fig. 6 is a top view of an alternative arrangement of the embodiment of Fig. 1;

Fig. 7 is a top view of another alternative arrangement of the embodiment of Fig. 1;

Fig. 8 is an exploded perspective view of a fixture block and piston according to another embodiment of the invention.

Detailed Description

Fig. 1 shows a cross section of a tooling fixture 1 according to a first embodiment of the invention. A number of cylinders 3 are provided in a fixture block 5. The lower ends of the cylinders 3 are connected with a manifold 7. A piston 9 is provided within each cylinder 3. The pistons 9 fit snugly within the cylinders 3 so that hydraulic pressure within the cylinders 3 will drive the pistons 9. Each piston 9 is connected with a rod 11. Movement of the piston 9 drives the rod 11 into and out of the block 5. Endcaps 13 are provided at the ends of the rods 11. According to one embodiment the endcaps are formed from a relatively soft material, such as a plastic, so that contact between a workpiece and the endcap 13 will not mar the surface of the workpiece. According to another embodiment the endcaps 13 are formed from a material that has a high coefficient of friction so that the workpiece will not tend to slip when in contact with the endcaps 13.

Fig. 2 shows a cross-section of a piston 9 and rod 11 according to an embodiment of the invention. The piston 9 includes an O-ring 10. When the piston 9 is inserted into the cylinder 3, the

O-ring 10 forms a slidable seal along the sides of the cylinder 3. The O-ring 10 may be formed from an elastomer, for example, buna rubber. Alternative seal arrangements are possible without departing from the invention.

As shown in Fig. 1, a tube 15 is connected with the manifold 7 by a valve 19. A pressure sensor 17 is connected with the tube 15. The pressure sensor 17 monitors the hydrostatic pressure of fluid in the manifold 7 and cylinders 3 and generates a signal that indicates the pressure in the cylinders 3. The pressure signal is monitored by a controller 18. According to one embodiment the pressure sensor 17 is an electronic sensor that generates a voltage that is proportional to the pressure in the cylinders 3. Alternatively, the pressure sensor is a pneumatic or mechanical sensor that generates a pneumatic or mechanical signal that indicates the pressure of the fluid in the cylinders 3. The valve 19 is opened or closed in response to a signal from the controller 18. According to one embodiment the valve 19 is a normally-closed valve that is opened by an electrical current provided by the controller 18. Alternatively, the valve 19 is a pneumatic or mechanical valve that is opened or closed in response to a pneumatic or mechanical signal from the controller 18.

The tube 15 is connected with the lower end of an accumulator 21. The accumulator 21 has a second pipe connecting its upper end to a second valve 29. According to one embodiment of the invention, valve 29 is a three-port valve that can be moved to a first or a second position. When valve 29 is in the first position, it connects the accumulator 21 with a third valve 27. When valve 29 is in the second position, the accumulator 21 is connected through tube 25 to a source of vacuum (not shown). The vacuum draws fluid into the accumulator 21 from the cylinders 3. According to this embodiment valve 27 is also a three-port valve that can be moved to a first or second position. When valve 27 is in the first position while valve 29 is in the first position, the accumulator 21 is

vented to the atmosphere through tube 31. When valve 27 is in the second position and valve 29 is in the first position, the accumulator 21 is connected by tube 23 with a compressed air supply (not shown) that drives fluid from the accumulator 21 to the cylinders 3. According to one embodiment of the invention, valves 27 and 29 are electrically operated valves that, when de-energized, are in their respective first positions.

According to another embodiment, the accumulator 21 includes a drive piston slidably fitted within a master cylinder holding the fluid. The drive piston is coupled to an actuator. In response to signals from the controller 18, the actuator raises the drive piston to draw fluid into the master cylinder from the cylinders 3 and lowers the drive piston to force fluid from the master cylinder to the cylinders 3.

The function of the accumulator 21 is to hold a sufficient volume of fluid to fill the cylinders 3 and manifold 7 when the pistons 9 are driven to the tops of the cylinders 3. The accumulator 21 and valves 19, 27 and 29 function together to supply the fluid to the cylinders 3 under the control of the controller 18. Other arrangements for performing these functions are well known to those skilled in the art and can be substituted while remaining within the scope of the invention.

The fixture block 5 rests on a tooling platform 6. According to one embodiment of the invention, the platform 6 is part of a screen printing machine and can be at a fixed height or moved up or down as indicated by arrow A by the screen printing machine. According to a further embodiment, the platform 6 is part of a placement machine and can be at a fixed height or moved up or down as indicated by arrow A by the placement machine.

According to one embodiment of the invention, the controller 18 is a programmable controller that executes programmed instructions stored in a memory. According to a further embodiment, the controller 18 is a computer programmed to monitor and control the functions of a screen printing machine and to direct the operations of the valves 19, 27 and 29 in conjunction with the operation of the screen printing machine. According to another embodiment, the controller 18 is a computer programmed to monitor and control the functions of a placement machine.

Operation of the tooling fixture 1 according to an embodiment of the invention will be described with reference to Figs. 3-5. As shown in Fig. 3, initially valve 19 is closed and valves 29 and 27 are in their first positions. All of the pistons 9 are at the bottom of the cylinders 3, and rods 11 are withdrawn into the block 5 to enable a workpiece 8 to be positioned above the tooling fixture 1. The workpiece 8 can be substantially flat or can have vertical features. According to one embodiment the workpiece 8 is a printed circuit board with a lower surface populated with electronic components. On command from the screen printer, the controller 18 signals the valve 19 to open and valve 27 to switch to its second position, allowing compressed air to flow to the accumulator 21, thereby causing fluid to flow from the accumulator 21 to the manifold 7 and cylinders 3. Fluid is forced into the cylinders 3, driving the pistons 9 towards the tops of the cylinders 3 and extending the rods 11 from the top of the block 5.

As each rod 11 encounters the surface of the workpiece 8 it will stop while the remaining rods 11 continue to rise, as shown in Fig. 4. When all rods 11 have contacted the surface of the workpiece 8, as shown in Fig. 5, or the corresponding piston 9 has reached the top of its cylinder 3, flow of fluid from the accumulator 21 to the manifold 7 will cease and the pressure in the manifold 7 and pipe 15 will increase rapidly. The pressure of the fluid in the manifold 7 and pipe 15 is

monitored by the pressure sensor 17. The controller 18 compares the pressure sensed by the sensor 17 with a predetermined threshold. When that threshold is exceeded, the controller 18 closes the valve 19 and switches valve 27 to its first position. With the valve 19 closed, the volume of fluid in the cylinders 3 and manifold 7 is fixed so that the workpiece 8 will not flex in response to force applied along the row of rods 11 supported by the pistons 9. In addition, force applied to the workpiece 8 at a single point will be resisted by the stiffness due to viscous flow of fluid between cylinders 3.

According to one embodiment of the invention, the workpiece 8 is a printed circuit board within a screen printing machine. After the tooling platform 6 has been raised to bring the upper surface of workpiece 8 into contact with the stencil (not shown) and the valve 19 closed, as shown in Fig. 5, a screen printing head (not shown) applies solder paste to selected portions of the top surface of the board. The screen printing head applies solder paste to the top surface of the printed circuit board along a line. According to this embodiment, the row of cylinders 3 is aligned with the screen printing head so that force applied by the printing head along the line is resisted by the row of rods 11.

According to another embodiment of the invention, the workpiece 8 is a printed circuit board within a placement machine. After the valve 19 is closed, as shown in Fig. 5, a pick-and-place head (not shown) presses electronic components onto selected areas on the top side of the board. Stiffness due to viscous flow of fluid among the cylinders 3 prevents the board from flexing in response to pressure applied by the pick-and-place head.

When the process that requires applying force to the top surface of the workpiece 8, for example, the screen printing or component placement operation, is complete, the controller 18 opens valve 19 and switches valve 29 to its second position to apply a vacuum to accumulator 21, drawing fluid from the cylinders 3 and retracting the rods 11 into the block 5. After sufficient time to allow all the rods 11 to be retracted, valve 19 is closed and valve 29 is switched to its first position. Then the workpiece 8 is replaced by a next workpiece 8 and the process is repeated.

The sequence of operations for supporting a workpiece 8 with the tooling fixture 1 according to the invention is not limited to the one described in relation to Figs. 3-5. Other sequences of operation can be used within the scope of the invention. For example, instead of extending the rods 11 until they all contact the workpiece 8, the rods 11 may first be all fully extended, with the tooling platform 6 starting in a lowered position. According to this embodiment the controller 18 opens the valve 19 and switches valve 29 to its first position and valve 27 to its second position so that the pistons 9 are driven to the top of the cylinders 3. Valve 27 is then switched to its first position connecting the accumulator 21 with the atmospheric vent via tube 31. The controller 18 causes the platform 6 to rise so that, as each rod 11 contacts the workpiece 8, it pushes down the pistons 9 into cylinders 3, displacing fluid from cylinders 3 to the accumulator 21. Back pressure due to viscous flow of the fluid keeps the rods 11 extended until they are pushed down by the workpiece 8. When the platform 6 reaches its upper position the controller 18 closes valve 19, locking the rods 11 in position. After use, the platform 6 is lowered, enabling the workpiece 8 to be replaced by the next workpiece.

It should be noted that the tooling fixture 1 according to the invention is not configured before it encounters the workpiece 8. The configuration of the rods 11 will conform to the surface

of the workpiece 8 regardless of the position or height of vertical features. As such, the tooling fixture 1 according to the invention will automatically adapt to each individual workpiece 8 irrespective of differences between types of workpieces.

Fig. 6 shows an array of rods 11 arranged on a fixture block 5 of a tooling fixture 1 according to an embodiment of the invention. Each of the rods 11 are connected with a piston 9 in a cylinder 3 arranged within the body of the block 5, as described according to the above embodiments. Each row of cylinders 3 are connected to a manifold 7 and valve 19 that supplies fluid to each of the cylinders 3 in that row. According to this embodiment, when air pressure is applied to the accumulator 21, fluid moves from the accumulator 21 into the cylinders 3 raising the rods 11. When all of the rods 11 have contacted the workpiece 8 the pressure sensed by pressure sensor 17 rises and the controller 18 simultaneously closes all valves 19. According to another embodiment of the invention, where the workpiece 8 does not span all of the rows of rods 11, the controller 18 is programmed to hold the valves 19 for rows that are not under the workpiece 8 closed throughout the operation so that the rods 11 in those rows remain retracted within the block 5.

Fig. 7 shows an array of rods 11 arranged on a fixture block 5 of a tooling fixture 1 according to a further embodiment of the invention. Each of the rods 11 are connected with a piston 9 in a cylinder 3 arranged within the body of the block 5, as described according to the above embodiments. The cylinders 3 are connected to a common manifold 7 that supplies fluid to each of the cylinders 3 simultaneously. This embodiment functions as above except that a single valve 19 controls the full array of rods 11. This embodiment is suitable for applications where a relatively light force is applied for a short period such as exists in placement machines, as under these

conditions, the stiffness of the system will prevent a single rod 11 or group of rods 11 being depressed forcing fluid from their respective cylinders 3 into other cylinders 3 and causing the other rods 11 to rise. For applications such as screen printing where much higher forces are applied, the force is applied along the length of the print head and the previous arrangement, in which rows of rods 11, aligned along the length of the print head, are each controlled from a separate valve 19 is more suitable, as these valves 19 prevent fluid from one row moving to an alternative row and prevent depression of the rods 11.

Fig. 8 shows an exploded view of a block segment 50 according to another embodiment of the invention. The block segments 50, each contain two rows of rods 11 and a plurality of such block segments 50 can be bolted together to form an array of rods 11, as shown in Figs. 6 or 7. The block segments 50, shown in Fig. 8, are each assembled from a manifold section 51, a cylinder section 53, and a top section 55. Grooves 57 are cut in the manifold section 51 to form the manifold 7. Outlet holes 59 are cut in the end of the manifold section 51 to intersect the grooves 57. These outlet holes 59 are connected with the valves 19, as shown in Figs. 6 and 7. Cylinders 3 are provided through the cylinder section 53. Pistons 9 and rods 11 are inserted into the cylinder section 53. The rods 11 extend through holes in the top section 55. The manifold sections 51, cylinder sections 53 and top section 55 are fixed to one another together by screws (not shown) that pass through counter-bored holes 61 in top plate 55, clearance holes 62 in cylinder sections 53 and into threaded holes 63 in manifold section 51. A gasket (not shown) may be placed between manifold section 51 and cylinder section 53 to form a fluid-tight seal.

The above embodiments are illustrative of the present invention. While these are presently considered the most practical and preferred embodiments, it is to be understood that the invention is

not limited by this disclosure. This invention is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the invention, as will be apparent to a person of ordinary skill in the art.

We claim:

1. A tooling fixture comprising:

a source of fluid;

a fixture block;

a plurality of cylinders within the fixture block;

a valve connected with the source of fluid and with the cylinders for controlling the flow of a fluid therebetween;

a pressure sensor connected with the cylinders, the pressure sensor generating a signal that indicates a pressure of the fluid in the cylinders;

a plurality of pistons slidably fitted into respective ones of the plurality of cylinders, ends of the pistons extending from a surface of the fixture block; and

a controller connected with the pressure sensor and the valve.

2. The fixture according to claim 1, wherein the source of fluid comprises an accumulator including a fixed volume container connected at a bottom end with the valve and connected at a top end to a source of gas for applying a pneumatic pressure to the fluid.

3. The fixture according to claim 2, wherein the accumulator further comprises a source of vacuum connected with the fixed volume container for applying a negative pneumatic pressure to the fluid.

4. The fixture according to claim 3, further comprising a compressed air supply valve connecting the source of pneumatic pressure with the fixed volume container and a vacuum supply valve connecting the source of vacuum with the fixed volume container, the compressed air and vacuum supply valves being controlled in response to signals from the controller.

5. The fixture according to claim 4, wherein the vacuum supply valve includes a three-port valve for connecting the fixed volume container with the vacuum source and connecting the fixed volume container with the compressed air supply valve and the compressed air supply valve includes a three-port valve for connecting the vacuum supply valve with the compressed air supply and connecting the vacuum supply valve with an atmospheric vent.

6. The fixture according to claim 1, wherein the cylinders are arranged in a two-dimensional array.

7. The fixture according to claim 1, wherein the cylinders are arranged in a row.

8. The fixture according to claim 1, wherein the fixture block further comprises a plurality of block segments, and wherein an at least one row of the cylinders is provided on each segment.

9. The fixture according to claim 1, wherein the controller closes the valve when the pressure of the fluid in the cylinders reaches a predetermined threshold.

10. The fixture according to claim 1, wherein the controller is a programmable controller executing programmed instructions stored in a memory.

11. The fixture according to claim 1, further comprising a printed circuit board disposed proximate to the surface of the fixture block within a screen printing machine.

12. The fixture according to claim 1, further comprising a printed circuit board disposed proximate to the surface of the fixture block within a placement machine.

13. The fixture according to claim 1, further comprising endcaps affixed to the ends of the pistons.

14. The fixture according to claim 1, wherein the pistons further comprise sealing rings, the sealing rings forming a sliding seal along walls of the cylinders.

15. A tooling fixture comprising:

accumulator means for providing a hydraulic fluid;

valve means for opening and closing a fluid path from the accumulator means;

a plurality of cylinders connected with the valve means;

pressure sensing means for sensing a pressure of fluid in the cylinders;

control means for controlling the accumulator means and the valve means; and

a plurality of pistons slidably disposed in the plurality of cylinders, ends thereof extending from the cylinders.

16. A tooling fixture for supporting a printed circuit board, the fixture comprising:

a source of fluid;

a plurality of valves, each connected with the accumulator;

a plurality of block segments connected with respective ones of the valves;

a plurality of cylinders, the cylinders being arranged in a row within the block segments and the row of cylinders in each block segment being connected with the respective valve;

a plurality of pistons, the pistons being disposed in the cylinders, ends of the pistons extending from surfaces of the block segments;

a pressure sensor connected with the plurality of cylinders; and

a controller connected with the actuator, the plurality of valves, and the pressure sensor.

17. The tooling fixture according to claim 16, wherein the source of fluid further comprises:

a fixed volume container connected at a bottom end thereof with the plurality of valves;

a source of compressed air;

a compressed air supply valve connecting the source of compressed air with a top end of the container;

a source of vacuum; and

a vacuum supply valve connecting the source of vacuum with the top end of the container,

wherein the controller is connected with the compressed air supply valve and the vacuum supply valve.

18. The fixture according to claim 16, wherein the controller controls the valves in response to signals from the pressure sensor.

19. The fixture according to claim 16, wherein a selected one of the plurality of valves is held closed so that cylinders connected with the selected valve are disabled.

20. A fixture block comprising:

a manifold section, the manifold section including a groove along a top surface thereof and an outlet hole on an end thereof intersecting the groove;

a cylinder section mounted to the top surface of the manifold section, the cylinder section including a plurality of cylinder holes therethrough, the cylinder holes being aligned with the groove;

a top section mounted to a top surface of the cylinder section; and

a plurality of pistons slidably disposed in the cylinder holes, ends thereof extending through holes in the top section.

21. The fixture according to claim 20, further comprising a gasket disposed between the manifold section and the cylinder section.

22. A method for supporting a workpiece comprising:

providing a fixture block proximate to the workpiece, the fixture block including a plurality of pistons disposed in a respective plurality of cylinders, ends of the pistons extending through a surface of the fixture block;

opening a valve connecting the plurality of cylinders with a source of hydraulic fluid;

applying a first force to the source of fluid to move the fluid out of the cylinders to pull the pistons toward the bottoms of the cylinders;

moving the fixture block to a predetermined distance from the workpiece;

applying a second force to the source of fluid to move the fluid into the cylinders to drive the pistons toward the tops of the cylinders, wherein ends of the pistons are extended from the surface of the block and contact a surface of the workpiece;

sensing a pressure of the fluid within the cylinders; and when the pressure reaches a predetermined threshold,

closing the valve.

23. The method according to claim 22, wherein the source of fluid comprises a fixed volume container connected at a bottom end with the valve and connected at a top end with a source of pneumatic pressure and a source of vacuum and wherein the step of applying the first force further comprises providing vacuum to the fixed volume container from the vacuum source and wherein the step of applying the second force further comprises providing pneumatic pressure to the container from the source of pneumatic pressure.

24. The method according to claim 22, wherein the plurality of cylinders are arranged in a plurality of rows, cylinders in each row being interconnected and each row being connected with a respective plurality of segment valves, the segment valves connecting the rows of cylinders with the

source of fluid, and wherein the step of closing the valve further comprises closing the plurality of segment valves.

25. The method according to claim 24, further comprising selecting a row that is to remain unextended and closing the segment valve connected with the selected row prior to the step of applying the second force.

26. The method according to claim 25, wherein the step of selecting further comprises determining a dimension of the workpiece and selecting the row to remain unextended based on the dimension of the workpiece.

27. The method according to claim 22, wherein the workpiece is a printed circuit board within a screen printing machine.

28. The method according to claim 22, wherein the workpiece is a printed circuit board within a placement machine.

29. A method for supporting a workpiece comprising:

providing a fixture block proximate to the workpiece, the fixture block including a plurality of pistons disposed in a respective plurality of cylinders, ends of the pistons extending through a surface of the fixture block;

opening a valve connecting the plurality of cylinders with a source of hydraulic fluid;

applying a force to the source of fluid to move the fluid into the cylinders to drive the pistons to the tops of the cylinders, wherein the ends of the pistons are extended from the surface of the fixture block;

moving the fixture block toward the workpiece so that the ends of the pistons contact a surface of the workpiece; when the fixture block reaches a predetermine distance from the workpiece,

stopping the movement of the fixture block; and

closing the valve.

ABSTRACT

A tooling fixture includes a number of cylinders in a fixture block fitted with pistons that drive support rods to extend from the surface of the block. The cylinders are connected with an accumulator by a valve that is controlled by a controller. A pressure sensor connected with the cylinders senses the pressure of hydraulic fluid in the cylinders and sends a pressure signal to the controller. The controller operates the valve and monitors the pressure sensor to determine when all the rods are in contact with the workpiece.

To support a workpiece the fixture is moved to a predetermined distance from the workpiece and force is applied to the accumulator to drive hydraulic fluid into the cylinders causing the support rods to extend and contact the work piece. Before all the rods have contacted the workpiece the pressure in the cylinders remains substantially constant. When all of the rods contact the workpiece the pressure in the cylinders rises. When the pressures reaches a predetermined pressure threshold, the controller closes the valve, thereby fixing the amount of force applied by the fixture to the workpiece.

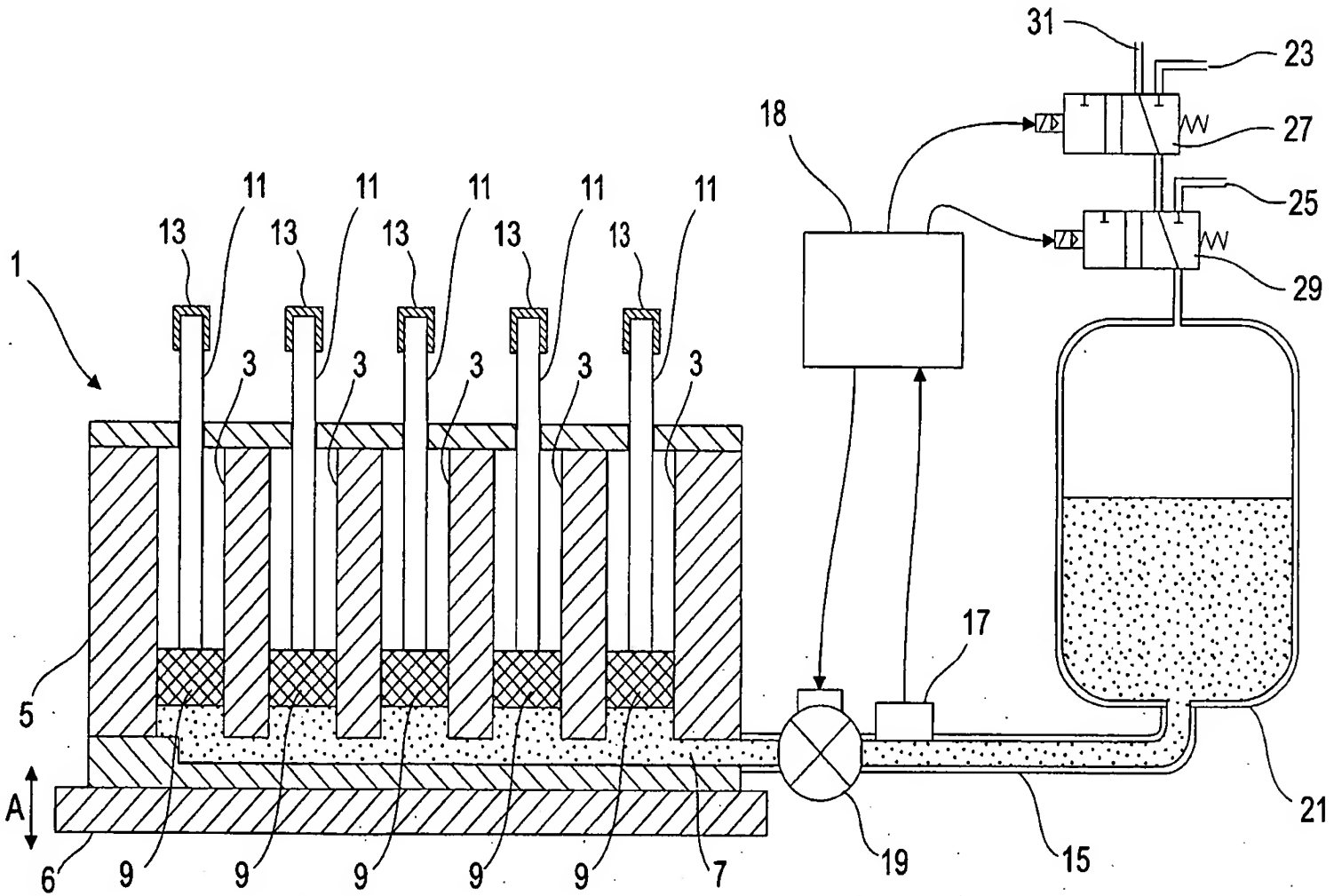

FIG. 1

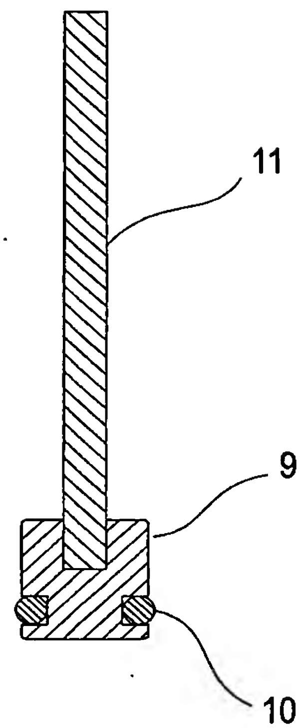

FIG. 2

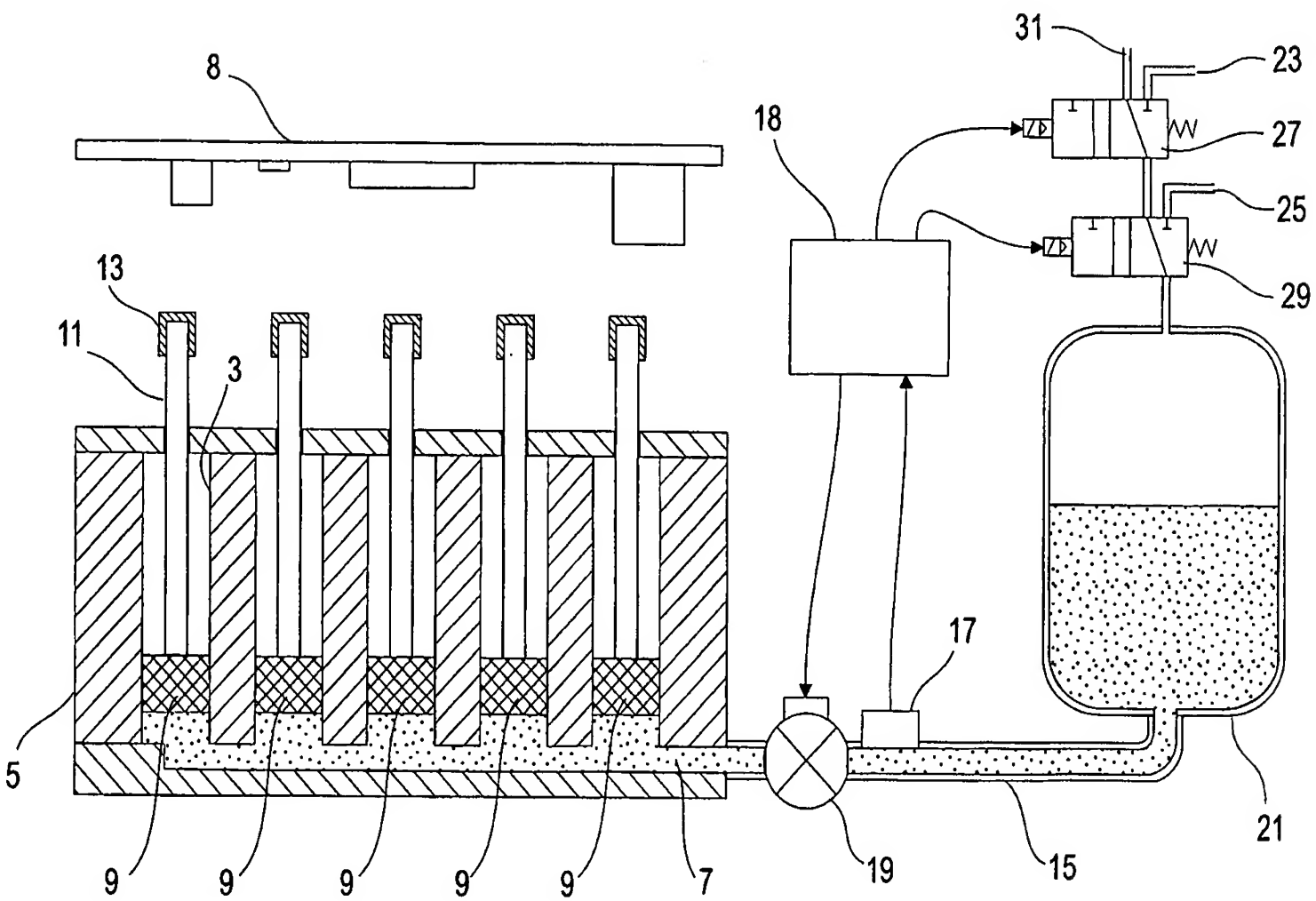

FIG. 3

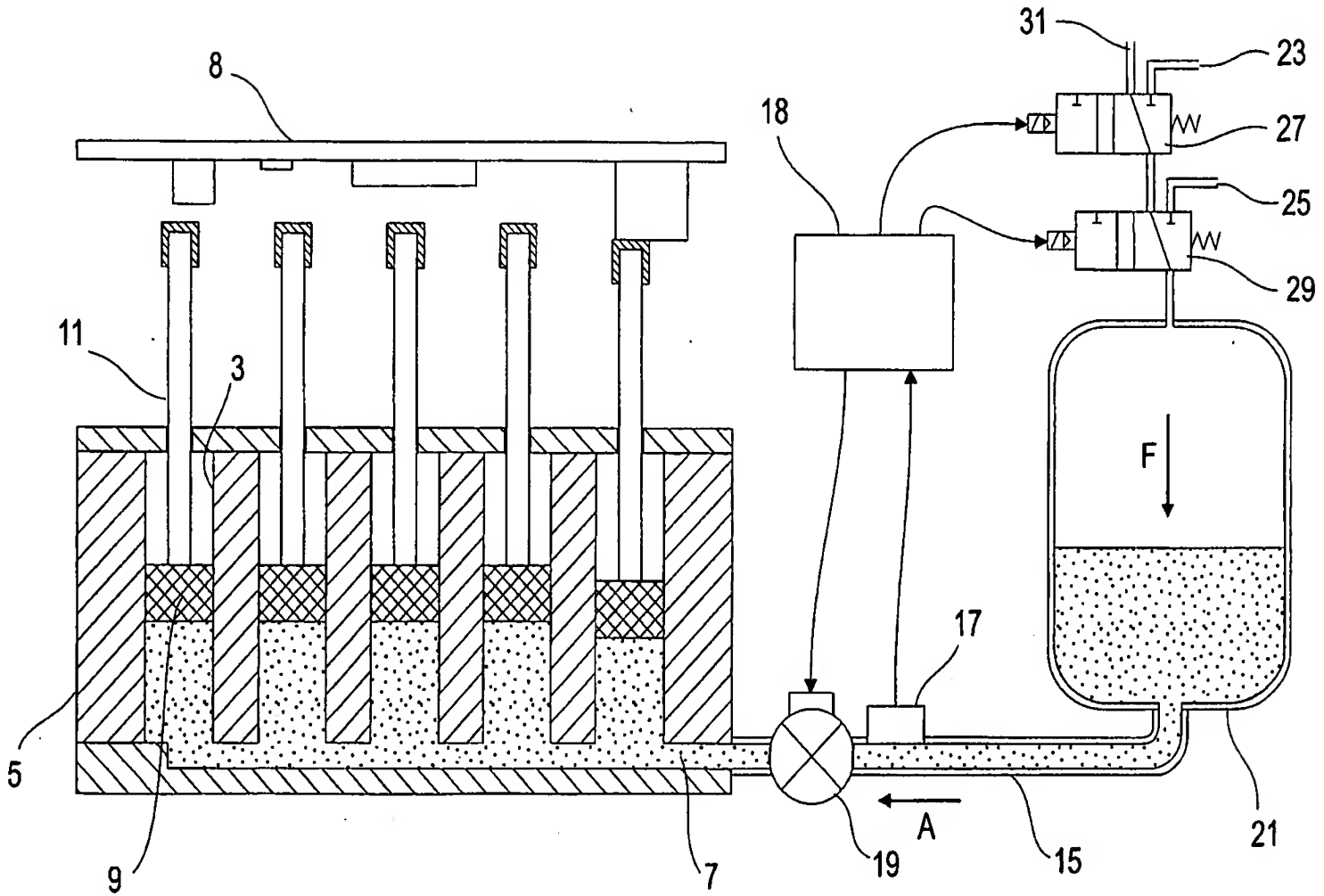

FIG. 4

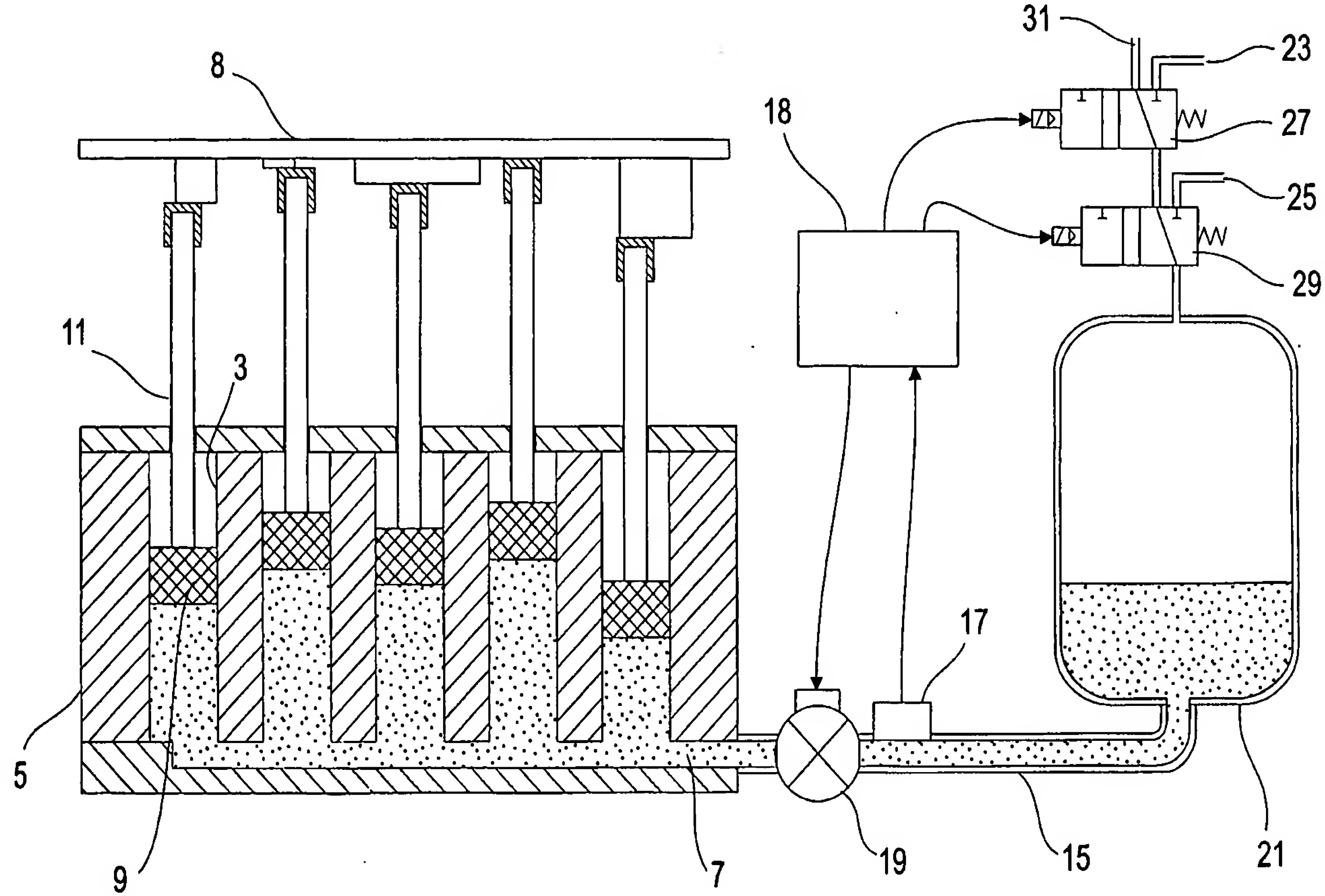

FIG. 5

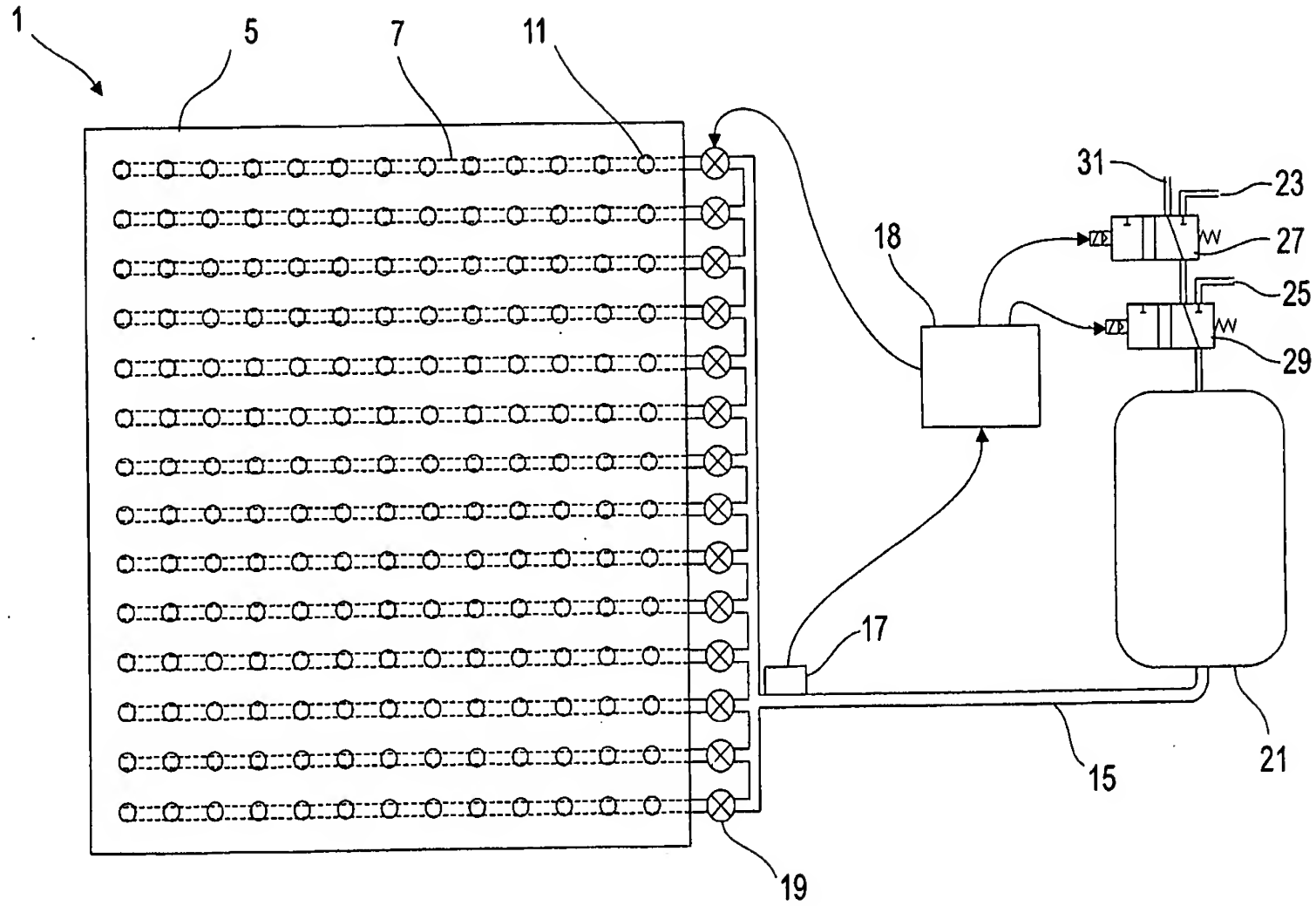

FIG. 6

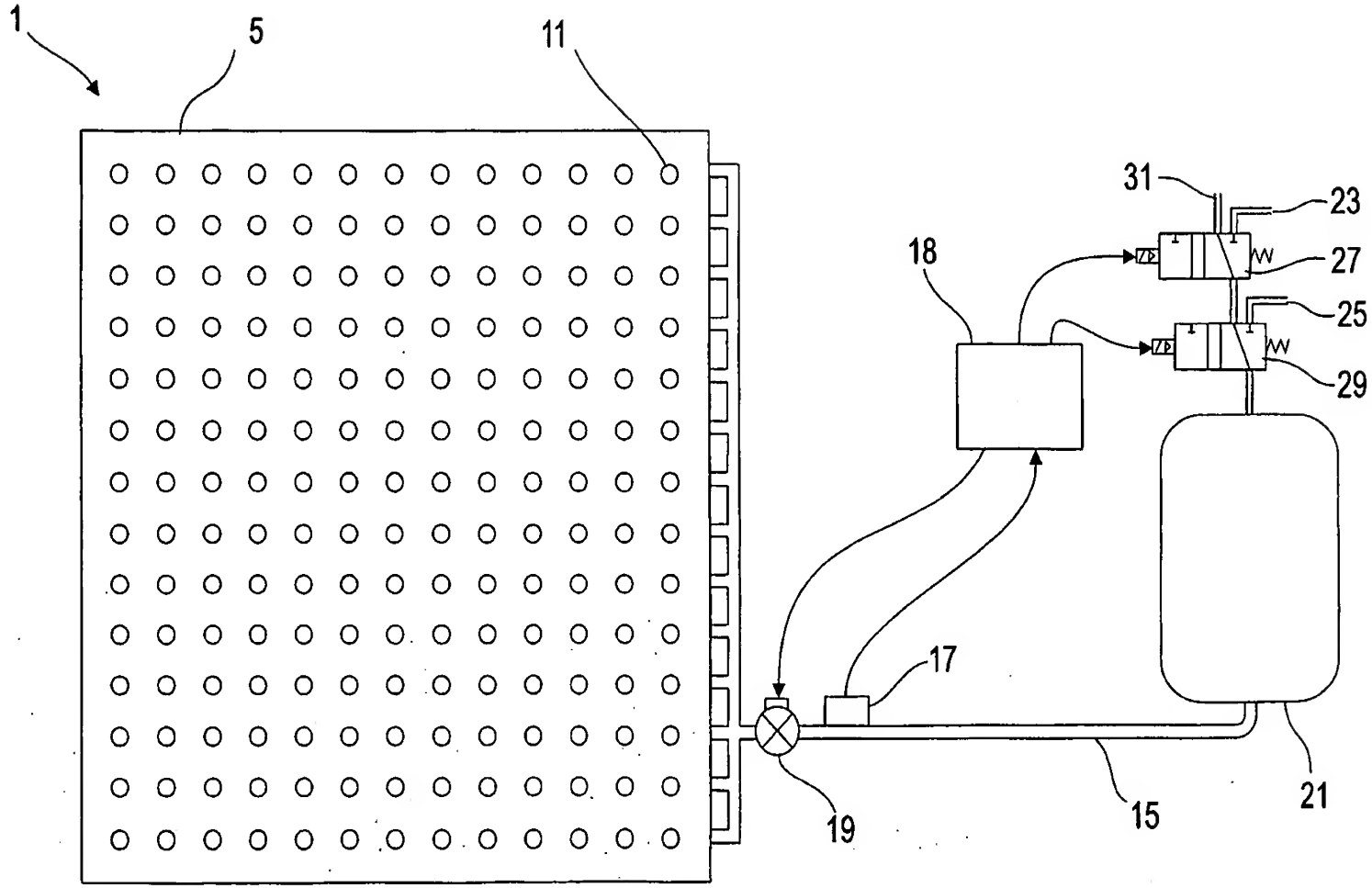

FIG. 7

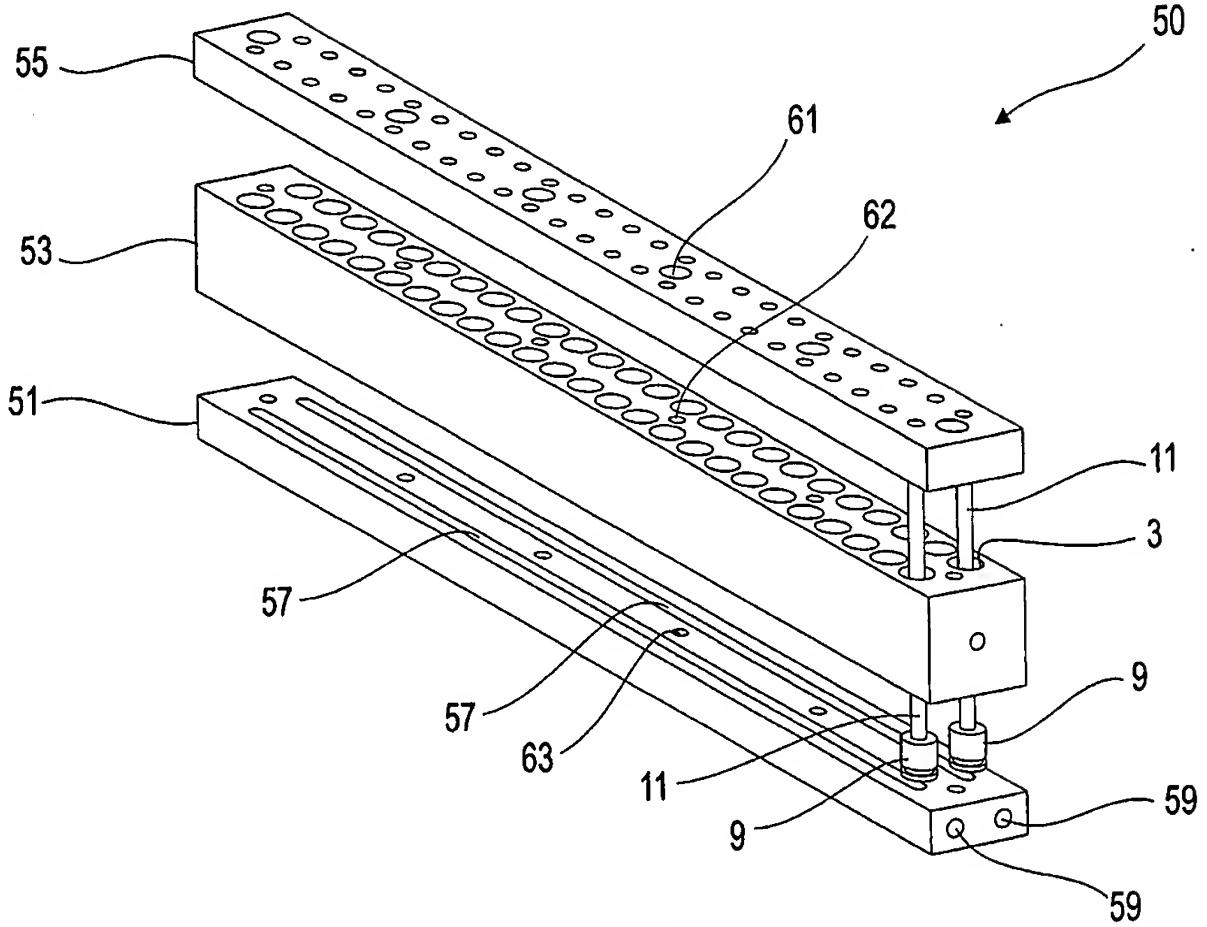

FIG. 8